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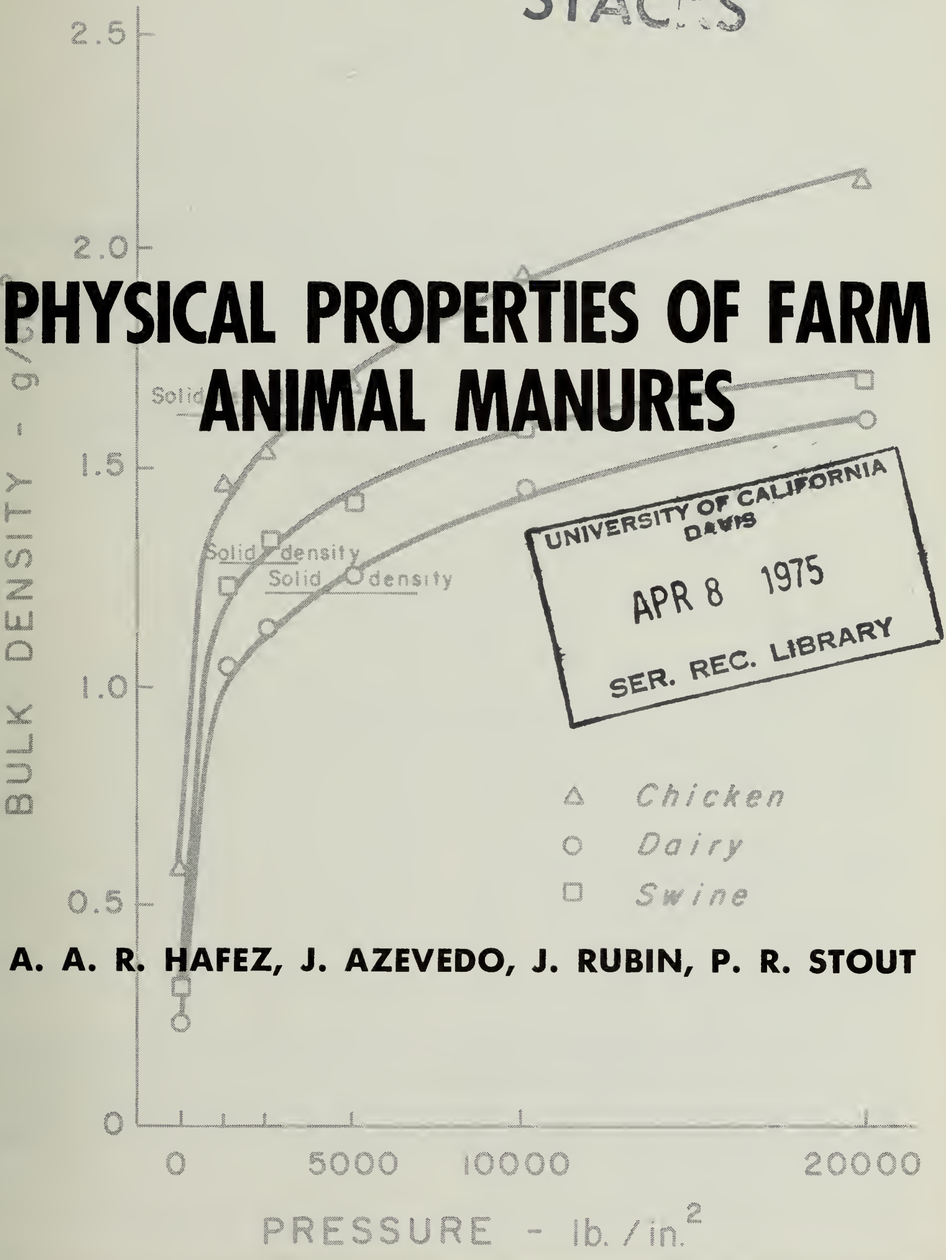
STACKS

PHYSICAL PROPERTIES OF FARM ANIMAL MANURES



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Physical properties of various fresh and aged manures were examined using techniques commonly applied in testing soils.

Characteristic differences between manures from poultry and other herbivorous livestock and between fresh and aged manures were discernible in these tests.

Dry, ground manures can be compressed into dense pellets one-fourth to one-eighth the volume of the original manures.

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PHYSICAL PROPERTIES OF FARM ANIMAL MANURES[1]

Introduction

Recent demands for more efficient manure handling, storage, treatment, and disposal systems for large populations of confined animals have revealed a lack of specific information about the physical properties of different animal manures. This paucity of basic physical data may have limited some engineering designs for handling manures to best advantage.

Physical benefits to soils from animal manure applications has been a subject of long-standing interest (Salter and Schollenberger, 1939), but physical properties of manures themselves have received very little direct study even though soil response should depend in part upon physical characteristics of manures that interact with soils.

This paper presents new research data on physical properties of a variety of farm animal manures and delineates sources of their physical variabilities. Hopefully, these data may help improve the predictability of benefits to be expected from incorporations of animal manures with soils.

METHODS

Samples of manure were gathered from various commercial animal production facilities throughout California with the view of obtaining samples that would symbolize various animal origins, subsequent treatments, and degrees of aging. Additional fresh samples of chicken, dairy, and beef manures were collected on the University farm at Davis. Fresh samples of cattle feces were taken from droppings less than 1-day-old and did not include urine. Chicken-manure samples characterized as fresh were scraped from the surface of manure accumulated beneath the poultry cages; a portion of these samples could have been as much as 3 days old.

Methods customarily used to characterize physical properties of soils were adapted for testing animal manures. The amount of organic versus mineral matter was determined by ashing; the ash—or fixed solids—was that fraction of oven-dry manure remaining after ignition at 550° C for 6 hours.

Particle size distributions. These were obtained from 50-g samples of fresh manure (approximately 10-g dry matter) after dispersing in a milkshake-type blender for fifteen minutes with approximately six ml of water per gram of fresh manure and then carefully wet-sieving the particles from the liquor. Each group of sieve-separated particles was dried and expressed as a percentage of the oven-dry weight of the original sample.

Particle density data. These data, which express average density of the particles in manure samples, were obtained by standard pycnometry with 95 per cent ethanol as the void-displacing liquid.

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[1] Submitted for publication April 2, 1974.

Bulk densities of dried manures. These were calculated from weight and volume measurements of 2-g samples of manure ground to pass a 2 mm sieve in 1-inch (2.54 cm) diameter metal cylinders. Pressure was applied to manures in these same cylinders with ascending pressures up to 20,000 pounds per square inch (1406 kg per m^2). Bulk densities were measured under pressure and without pressure after each increment of pressure applied.

Water imbibition and swelling. Manures pelleted with compression were exposed to a free water surface at one side and allowed to absorb water freely by capillary contact. Amounts of water absorbed and changes in volume of the pellets after absorbtion were measured.

RESULTS AND DISCUSSION

Average ash contents of fresh dairy feces (7 samples), fresh chicken manure (7 samples), and fresh beef feces (9 samples) were 15.6 ± 3.5, 32.6 ± 3.5, and 20.5 ± 7.0 per cent, respectively. Ash contents of fresh beef and dairy feces were quite similar with the exception of one abnormally high value for beef manure. The ash content of fresh poultry manure was uniformly higher than that of ruminant feces because of the considerable amount of grit in poultry rations.

Marked differences in ash content between manures from various animal species are less discernible after aging (Appendix A). The relative ash contents of manures increase with decomposition losses from carbonaceous materials. Aged corral scrapings, with various soil contents, had the highest ash contents, up to 70 per cent ash in one sample. Manures that had been mixed or commercially composted with carbonaceous litter materials had relatively low ash contents.

Particle densities of fresh dairy cattle (7 samples), chicken (7 samples), beef cattle (9 samples), and horse (1 sample only) manures averaged 1.17 ± 0.15, 1.55 ± 0.13, 1.33 ± 0.08, and 0.98 g per cm^3, respectively. Aging and composting manures generally increased their particle densities, while additions of carbonaceous litter or bedding decreased these values. Large strawy fibers found in herbivorous animal manures had densities of 0.91 g per cm^3, and particle densities of manures containing large proportions of these fibers (e.g. dairy and horse manures) approached that of water. Fibers of density lower than 1.0 tend to float in manure holding tanks, ponds, or other aqueous storage or treatment facilities. Nuisance surface mats of floating manure particles can be effectively controlled by mechanical pre-separation of the fibrous particles (Fairbank and Bramhall, 1968). The relatively high density values for poultry manures probably reflect the grinding processes of the poultry gizzard as well as presence of grit in the poultry diet. Some mineral calcium sources admixed in the rations of laying hens, for example, can have densities of 2 or greater (Sobel, 1966). However, feathers in poultry manure have low densities and can also form nuisance mats on storage ponds.

Differences between particle-size distributions of fresh poultry and ruminant manures is most striking at the coarse-particle size (greater than 2 mm). The percentage of poultry fresh manure particles greater than 2 mm averages less than 4 per cent by weight and consists mostly of feathers and a few pieces of grit. Coarse fractions of ruminant feces consist of fibrous particles of partially-digested strawy feeds and comprise more than 13 per cent of the dry weight of the manure (Appendix B and C). The fraction of small particles having diameters ranging from 50 to 250 μ is generally larger in poultry manure than in ruminant feces. The over-all effect of differences between poultry and ruminant manure particle sizes is a marked shift in the average geometrical mean diameter (GMD) from approximately 108 μ in poultry manure to 140 to 170 μ in ruminant feces.

Herbivorous animals lacking a specialized rumen where cellulosic materials are attacked by microorganisms, pass greater proportions of strawy feed materials on to their feces. Both horse and swine manures are characteristically fibrous, with approximately 43 and 32 per cent of their respective feces consisting of coarse particles greater than 2 mm. The geometrical mean diameter of one sample each of horse and swine manure was 376 and 247 μ, respectively.

Measured particle-size distributions of aged manures may reflect the difficulty of separating individual particles in dried manures as well as differences caused by aging or digestion processes and rations of different animal species. Particles in dried manures had attained a certain cohesiveness that resisted separation in the blender, and as a result coarser fractions appear at the expense of the fine-particle fractions (Appendix D). Additions of bedding or litter to the manures increase the percentages of coarse particles and the GMD of the sample.

Unlike solid-density values, bulk density values for dried manures are "apparent densities" that reflect combinations of void spaces in the porous manures as well as the real densities of the solid matter. The bulk densities of loose, ground animal manures at air-dry moisture contents ranged from 0.20 to 0.59 g per cm^3 (Appendix E), with poultry manures having the highest densities. Bulk densities increased rapidly with small increments of pressure up to about 1250 pounds per square inch and then increased more slowly at higher compacting pressures (Appendices E and F). Compression of individual manure particles in addition to compaction of aggregated particles were indicated since bulk densities at pressures of 5,000 pounds per square inch surpassed solid densities. At maximum pressures applied (20,000 pounds per square inch) bulk-density values ranged from four to eight times the original bulk densities of the ground manures.

Elasticity of compressed manures was calculated from the difference in densities of manure pellets under pressure and after release from pressure. The elastic spring-back of the pellets on release from pressure averaged 22 per cent of the compressed volume.

In most cases, limited moisture added to the air-dry manures increased their compactability at moderate pressures (Appendix G). Of three moistures additions tested (0, 10, and 20 per cent), 10 per cent moisture added to air-dry manure seemed to be optimum for compactability of chicken and dairy manures. Swine manure required less additional moisture. Higher moistures generally decreased compactability and, in some cases, fluidized the sample sufficiently to preclude measurement.

Manure pellets previously compressed at a pressure of 20,000 pounds per square inch absorbed water rapidly when exposed to a free water surface at one side. Volumes of swollen pellets ranged from one to five times the original dry, compressed volumes, with more fibrous manures having greater expansions. For example, dairy manure quickly reached a water-adsorption plateau after 90 minutes (Appendix H) whereas chicken manure adsorbed water more slowly and reached a much lower plateau after 150 minutes. Wet, swollen manure pellets were very pliable, and the manure particles could be dispersed with little effort.

Pelleted manures may have a definite transportation and storage advantage if economics permit pelleting or cubing of manures. Such compaction techniques may also be useful if the manure is to be used as animal feed or as fuel.

CONCLUSIONS

Farm animal manure samples were collected from throughout California, and their physical properties were examined by adapting standard techniques normally applied to the examination of soil physical properties. Physical differences between poultry and animal manures and between fresh and aged manures can be readily demonstrated using standard methods with few modifications. Poultry manures generally had higher ash contents, smaller mean-particle sizes, and higher solid and bulk densities than did manures from other animals. Manures from horse and swine had higher mean-particle sizes than manures from ruminants or poultry.

Dry, ground manures can be compressed to one-fourth to one-eighth their original volume. Compaction and compression with moderate pressures (up to about 5000 pounds per square inch) are generally aided by small amounts of water added to the air-dry manures. Pelleted manures swell rapidly upon contact with water.

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APPENDIX A

ASH CONTENT AND PARTICLE DENSITY OF SOME AGED AND TREATED ANIMAL MANURES

Notes on source of manure samples	Per cent ash (dry-wt. basis)	Particle density (g/cm^3)
DAIRY		
dry corral	36.4	1.43
manure spread wet on land	29.8	1.41
fibrous particles from manure separator	7.8	0.91
composted commercially	51.0	1.66
ground, composted	53.4	1.84
composted commercially	49.9	1.70
CHICKEN		
aged 2 weeks	32.6	1.52
dried, ground commercially	33.9	1.44
from "deep pit" housing	39.0	1.55
stockpiled, aged	43.4	1.82
aged with wood shaving litter	12.9	1.53
aged and fresh mixed	40.3	1.60
composted with wood shavings commercially	27.4	1.41
dried, ground commercially	29.3	1.41
BEEF		
corral scrapings	34.3	1.44
stockpiled, aged	37.1	1.71
composted, ground commercially	70.2	2.00
composted, ground commercially	51.9	1.58
HORSE		
aged	17.6	1.13
aged, dry	10.7	1.11

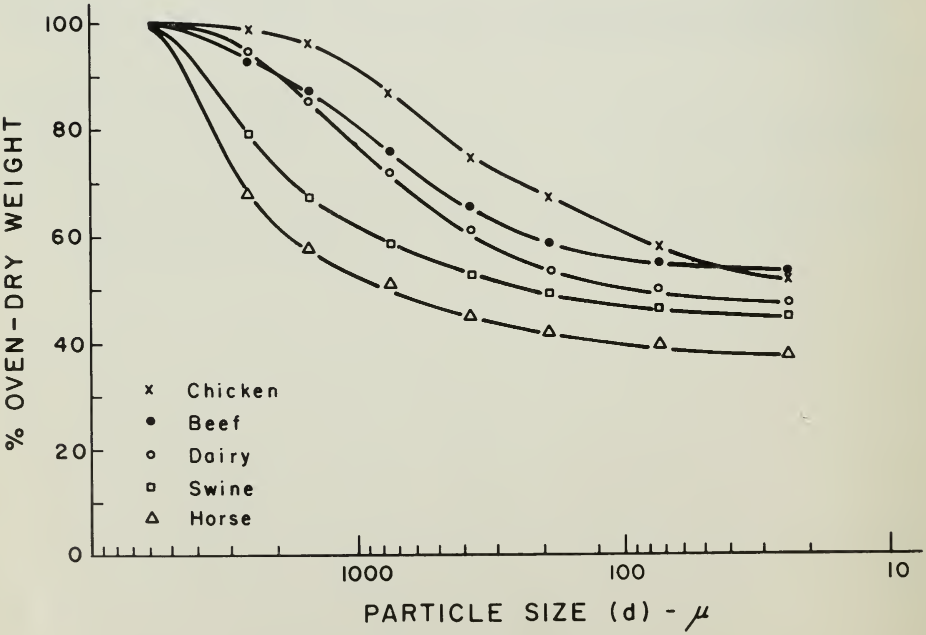
APPENDIX B

AVERAGE PARTICLE SIZE DISTRIBUTION OF DIFFERENT TYPES OF FRESH MANURES

Manure type	>2 mm	2–1 mm	1.0–0.5 mm	0.5–0.25 mm	250–125 μ	125–50 μ	<50 μ	GMD*
	per cent oven-dry basis							μ
Dairy cattle (5 samples)	14.56	13.54	10.91	7.18	3.71	2.35	47.76	171
Chicken (7 samples)	3.77	9.18	12.01	7.95	9.10	6.07	51.93	108
Beef Cattle (5 samples)	13.65	11.14	9.56	7.13	3.18	2.40	52.95	140
Horse (1 sample)	43.43	6.31	5.31	3.13	2.35	2.00	37.48	376
Swine (1 sample)	32.48	9.13	5.71	3.37	2.26	1.79	45.27	247

* Geometrical mean diameter (GMD) $= \exp\left[\sum_{i=1}^{n} w_i \log \bar{x}_i / \sum_{i=1}^{n} w_i\right]$ where w_i = weight of particle in a size class with an average diameter $\bar{x}_i$.

APPENDIX C



Particle size distributions of some fresh manures.

APPENDIX D

PARTICLE SIZE DISTRIBUTION OF VARIOUS TYPES OF AGED AND TREATED ANIMAL MANURES

Notes on source of manure sample	Particle size >2 mm	 2–1 mm	 1.0–0.5 mm	 0.5–0.25 mm	 250–125 μ	 125–50 μ	 50 μ	GMD*
	per cent oven-dry basis							μ
DAIRY								
aged, dry	23.12	10.35	2.59	6.52	1.30	0.58	55.58	157
dry corral	32.34	10.72	11.30	12.86	3.27	0.59	28.95	412
composted commercially	50.51	7.56	11.34	12.77	3.75	0.45	44.34	212
ground, composted	22.90	10.89	16.33	8.52	5.12	1.38	34.86	292
composted commercially	10.83	8.99	8.09	15.45	10.59	3.08	43.01	156
CHICKEN								
dried, ground commercially	0.12	12.07	26.52	16.28	12.40	2.14	30.49	209
stockpiled, aged	5.32	12.82	19.44	11.67	8.93	3.15	38.69	180
aged with wood shaving litter	27.08	12.75	9.95	7.51	5.84	1.58	35.51	306
composted with wood shavings	23.13	14.08	9.70	12.06	5.85	1.24	34.44	304
dried, ground commercially	9.39	21.96	11.90	4.41	12.79	4.42	35.16	219
BEEF								
corral scrapings	13.56	12.57	9.51	9.55	3.08	1.42	50.32	154
stockpiled, aged	8.76	8.01	11.93	16.48	6.47	6.55	47.83	142
composted, ground commercially	8.44	6.92	15.07	16.64	5.30	6.16	41.50	157
composted, ground commercially	10.76	6.99	9.48	20.97	7.80	1.62	42.40	162
HORSE								
aged	44.09	6.68	4.00	5.14	1.25	0.59	38.25	386
aged	71.03	3.13	2.17	4.53	0.69	0.51	17.97	1173
SWINE								
aged	39.14	2.90	5.19	4.34	1.90	0.68	45.94	271

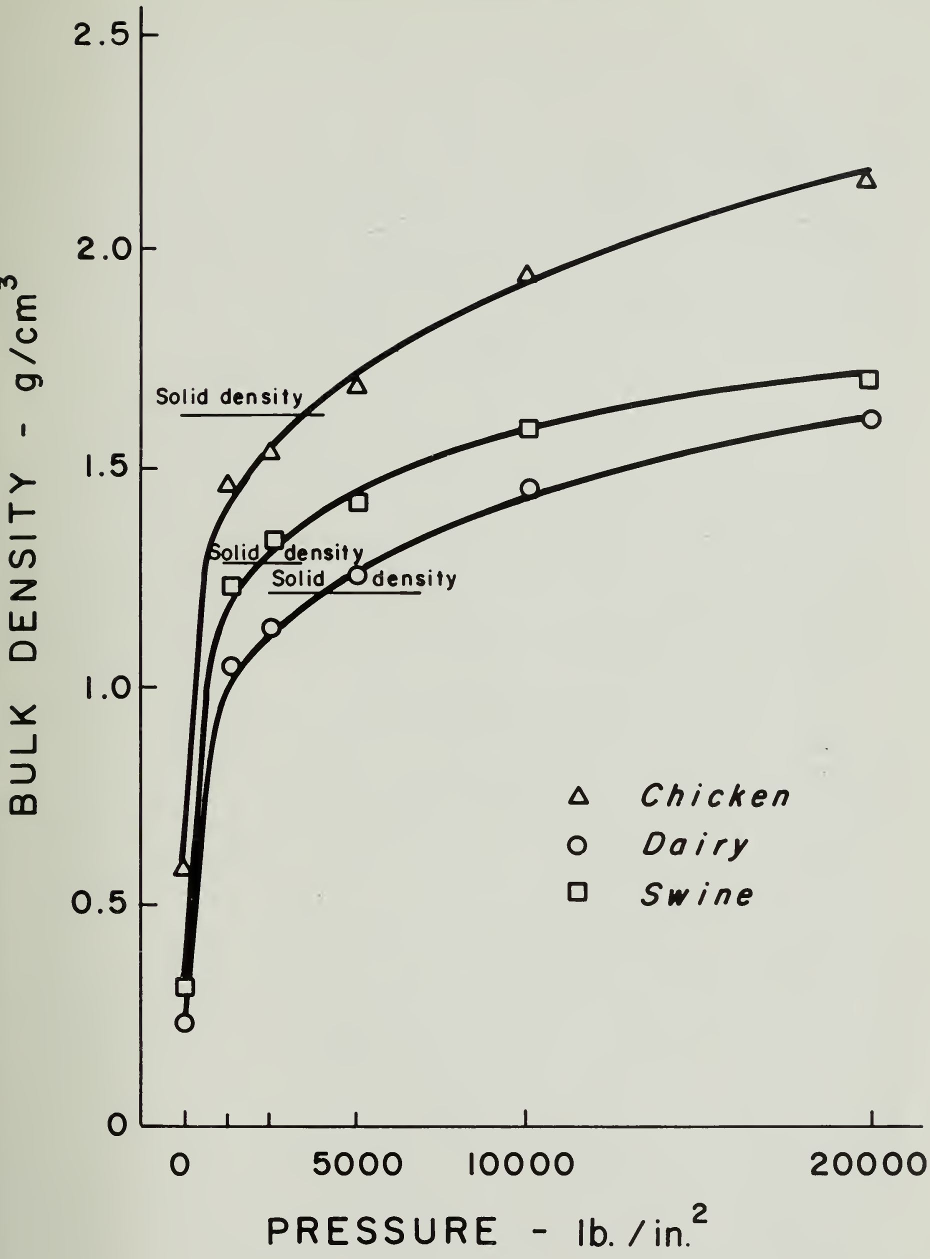
APPENDIX E

BULK DENSITY OF DIFFERENT TYPES OF AIR-DRY, GROUND ANIMAL MANURES AS A FUNCTION OF COMPRESSION

		Pressure applied (lb./in.^{2})					
		0	1250	2500	5000	10000	20000
Manure type		*bulk density* (g/cm^3) *					
Chicken	Press		1.61	1.75	1.95	2.29	2.61
	Release	0.58	1.46	1.53	1.68	1.93	2.16
Chicken and wood shaving bedding	Press		1.28	1.42	1.59	1.95	2.30
	Release	0.31	1.08	1.19	1.35	1.61	1.72
Turkey	Press		1.55	1.75	1.95	2.20	2.67
	Release	0.41	1.39	1.48	1.61	1.80	1.95
Turkey and rice hull bedding	Press		1.39	1.51	1.64	2.09	2.50
	Release	0.50	1.15	1.27	1.39	1.66	1.98
Beef	Press		1.28	1.40	1.61	1.92	2.39
	Release	0.28	1.08	1.17	1.28	1.53	1.78
Beef fed on alfalfa, rice hull bedding	Press		1.49	1.59	1.80	2.12	2.50
	Release	0.30	1.22	1.32	1.42	1.63	1.77
Beef fed on grain, rice hull bedding	Press		1.40	1.51	1.68	2.06	2.40
	Release	0.30	1.11	1.18	1.30	1.49	1.68
Dairy	Press		1.29	1.44	1.57	1.95	2.24
	Release	0.23	1.05	1.14	1.25	1.45	1.61
Horse	Press		1.35	1.45	1.61	1.92	2.33
	Release	0.20	1.06	1.19	1.35	1.55	1.61
Swine	Press		1.49	1.61	1.75	2.01	2.33
	Release	0.31	1.23	1.34	1.42	1.59	1.70

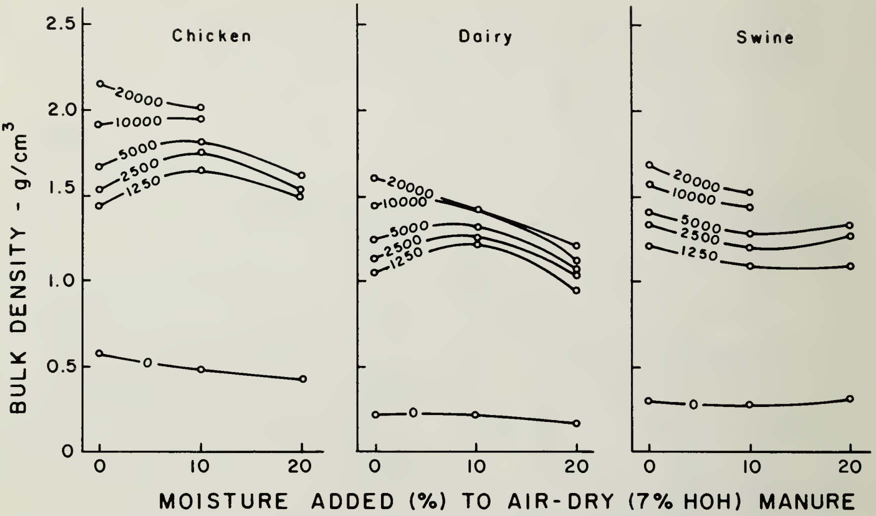
* Figures listed are the average of three replicates.

APPENDIX F



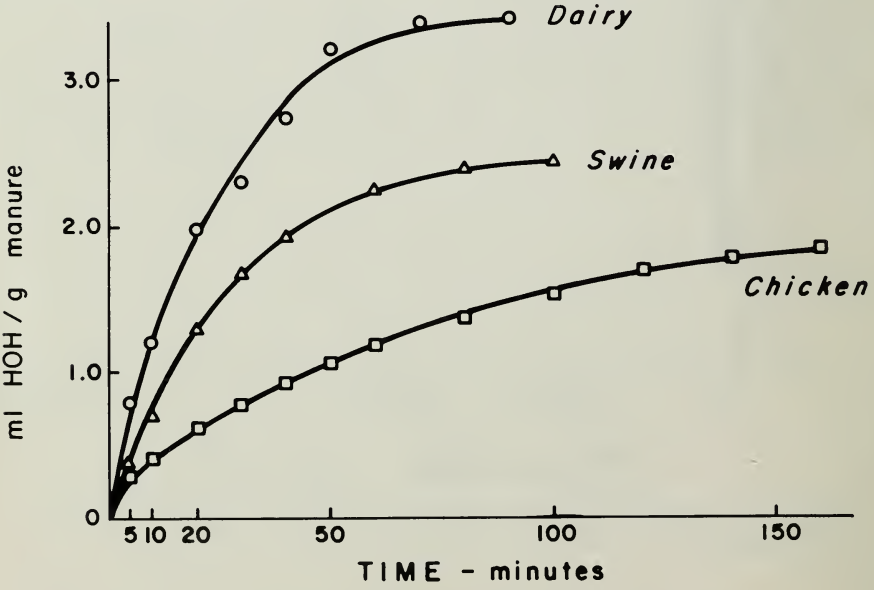
Comparison of bulk densities of air-dry chicken, dairy, and swine manures as functions of compression.

APPENDIX G



Effect of moisture on compressibility of chicken, dairy and swine manures at pressures ranging up to 20,000 lb./in.^{2} Numbers within curves (0, 1250, etc.) refer to compressive pressures lb./in.^{2} at which respective moisture-density curves were obtained.

APPENDIX H



Rate of water adsorption by pelleted chicken, dairy, and swine manures.

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